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Feasibility of solar thermal collectors usage in dwelling apartments in Mashhad, the second megacity of Iran

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ABSTRACT

Today, the concept of net zero-energy buildings has become a major concern regarding fossil fuels combustion side effects, such as air pollution or global warming. Nonetheless, NG (natural gas) is a kind of fossil fuels which is widely combusted in Iran to meet various buildings heating demand. However, the objective of this study is mitigating NG flaring by substituting solar energy as an auxiliary energy source in dwelling buildings. To promote this idea a solar thermal collector is designed. This application is installed on the roof and is responsible to preheat either water circulates in radiators loop, to provide space heating, or domestic hot water to supply washing demand in residential apartments. Indeed, in case of utilizing this application fewer NG will be combusted for rising input water temperature to required value. This approach, consequently leads to decline CO_2 emission eventually. Also a dwelling complex including 136 flat apartments is taken into account to perform this research. This complex is situated in Mashhad, the second megacity in Iran. Besides, to evaluate this potential four steps have been taking into account. In the first step annual DHW (domestic hot water) load is computed. Second, heating load is achieved according to actual NG consumption (the sole energy source in case study). In the third step the net annual energy which can be gain by solar absorber is calculated. Finally, annual NG economy, invest return time of solar collector and CO_2 avoided are evaluated 203,000 m^3, 4 yr and 380 t/yr, respectively.

Contents

1. Introduction

Undoubtedly, energy is an essential requirement and basic need for continuity of development particularly in industrial societies and plays a pivotal role in human welfare. As these societies grow the amount of energy usage grows as well. The building sector consumes about 40% of annual energy in Iran and has considerable portion in energy demand [1]. Fossil fuels have still the lion share of energy marketing. Iran is a well-known country in terms of either producing or consuming hydrocarbon fuel resources including Natural Gas or Crude Oil [2]. NG(natural gas) network is widely distributed among several cities of Iran and is responsible to meet heating demand for various building

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Nomenclature

I_b	clear sky beam radiation (MJ/m^2 h)
I_d	clear sky diffuse radiation (MJ/m^2 h)
A_c	collector area (m^2)
T_i	liquid inlet temperature in collector tube (°C)
T_a	ambient temperature (°C)
$h_{c,p-c}$	convection coefficient between plate and cover (W/m^2 °C)
$h_{r,p-c}$	radiation coefficient between plate and cover (W/m^2 °C)
$h_{r,c-a}$	radiation coefficient between cover and air (W/m^2 °C)
F_R	collector flow factor dimensionless
β	collector slope degree
$(\tau\alpha)_b$	beam absorptance-transmittance product unit less
$(\tau\alpha)_d$	diffuse absorptance-transmittance product unit less
θ	angle of incidence degree
θ_z	Zenith angle degree
S	absorbed radiation per unit area of collector (MJ/m^2)
U_t	overall loss coefficient (W/m^2 °C)
Q	net energy which can be gain by collector (MJ)
Nu	Nusselt number
Ra	Rayleig number
V	volume of domestic hot water (l)

sectors. Iran ranked the first NG producer, consumer and carbon provider among the Middle East countries in 2011 [2]. Consequently, the biggest environmental issue that Iran currently faces is air pollution owing to carbon emission. However, in 2011 total emissions from the combustion of NG in this country reached to approximately 334 million metric tons of carbon meanwhile it was almost 230 million metric tons in 2005 [2]. Tables 1 and 2 depict CO_2 emission from the flaring of NG among some developed and Middle East countries between 2005 until 2011, respectively. As it can be seen, Iran has third rank after two huge countries, U.S. and Russia, and the first in the Middle East in this issue. Moreover, Graphs 1 and 2 show the rising trend of Iran's CO_2 emission between 2005 until 2011 either globally or in the Middle East [2]. The share of Iran in this subject is 3 and 20% in the Middle East and worldwide, respectively [2]. Total NG consumption has reached from 105 to approximate 153.34 billion cubic meters between 2005 until 2011 [2]. Whilst, Saudi Arabia as a well-known hydrocarbon consumer has reached from 72 to 100 billion cubic meters among same years and has the second place [2]. Table 3 also lists NG consumption in the Middle East from 2005 until 2011 [2]. Additionally, Graph 3 shows Iran's rising trend of NG consumption from 2005 until 2011 and makes comparison between some major countries [2].

These statistics prove Iran has experienced rising trend either in NG consumption or in carbon emission in these recent years. Yet, the consequence of this heavy dependence on hydrocarbon fuels is becoming increasingly concerning. Several renewable resources – based on their feasibility – can provide supplementary sources for partially substituting fossil fuels. Currently, renewable energy contributes to about 11% of the world primary energy and this is expected to increase to 60% by 2070 [3]. Even in the Middle East countries, as the world's heart of the hydrocarbon resources, it is estimated that the renewable proportion in electricity production will reach 16% in year 2035 from 1% in year 2008 [3]. However, due to notable climatic diversity, Iran enjoys rich renewable natural resources including wind, solar and tidal waves. The

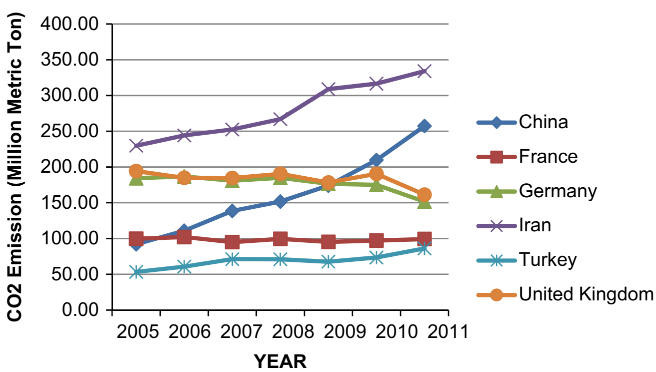
Table 1
CO_2 emission from the flaring of natural gas (million metric tons) [2].

Year	2005	2006	2007	2008	2009	2010	2011
China	92.08	110.95	138.59	151.70	173.94	209.74	257.33
France	99.81	102.12	94.99	99.59	95.26	97.20	99.33
Germany	184.32	186.86	180.87	184.92	176.60	175.16	151.60
India	71.85	77.13	82.17	85.17	105.60	127.33	126.32
Iran	229.75	244.16	252.48	266.90	308.92	316.51	333.97
Italy	165.35	161.94	162.73	162.70	149.56	159.28	149.35
Russia	806.77	856.56	859.04	881.91	769.90	845.63	1009.73
Turkey	53.30	60.77	71.19	71.00	67.64	73.44	86.13
United Kingdom	194.31	184.93	184.60	190.55	178.35	190.43	161.37
United States	1189.60	1174.79	1251.13	1262.04	1239.28	1299.74	1317.63
World	5677.85	5829.30	6011.63	6220.89	5985.53	6420.43	6754.72

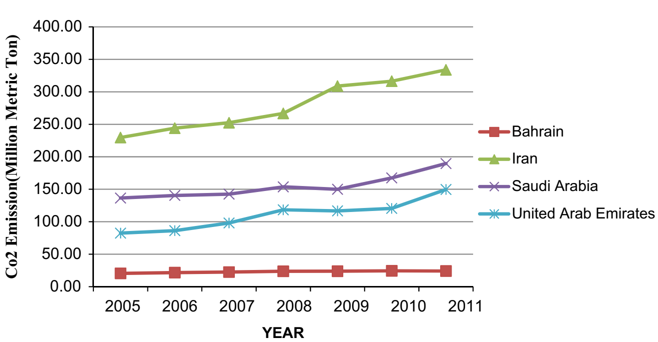
Table 2
CO_2 emissions from the consumption and flaring of natural gas in the middle east between 2005 until 2011(million metric tons)[2].

Year	2005	2006	2007	2008	2009	2010	2011
Middle East	593.58	623.54	644.14	699.20	746.61	790.19	851.51
Bahrain	20.47	21.65	22.51	23.72	23.85	24.41	24.12
Iran	229.75	244.16	252.48	266.90	308.92	316.51	333.97
Iraq	16.78	17.10	15.56	14.24	14.58	15.91	18.73
Jordan	3.06	4.41	5.10	5.75	6.02	5.38	2.03
Kuwait	25.28	25.31	23.49	24.63	22.16	24.51	27.56
Oman	19.28	23.12	23.28	28.33	30.71	35.89	35.15
Qatar	46.46	46.81	47.19	49.00	51.58	50.79	46.06
Saudi Arabia	136.51	140.52	142.58	153.73	149.93	167.53	189.65
Syria	12.06	12.29	11.64	11.72	14.33	18.52	15.82
United Arab Emirates	82.51	86.26	98.08	118.39	116.72	120.53	149.71

average annual radiation of sun is about 2000 kW h/m^2 in Iran with more than 7.7 h/day in central areas, while Germany, as one of the pioneer countries in solar energy exploitation enjoys about 1200 kW h/m^2 yr of solar radiation [4] Figs. 1 and 2 show this comparison. This paper focuses on the feasibility of solar thermal collectors' usage as the heating supplier for residential apartments in Mashhad the second megacity in Iran. Meanwhile, monthly average radiation on a horizontal surface is measured about 4.71 kW h/m^2 day according to NASA Surface meteorology and Solar Energy [5]. To make comparison, Antalya as a well-known example in using solar technologies, enjoys average amount of 4.5 kW h/m^2 day radiations [5]. This comparison and the following calculations in this study implicate that these applications can be a supplementary energy source to provide partially heating demand in residential apartments. Furthermore, initial investment payback time and annual GHG reduction is discussed in more detail.



Graph 1. CO_2 emission trend of Iran and some major countries in the globe [2].



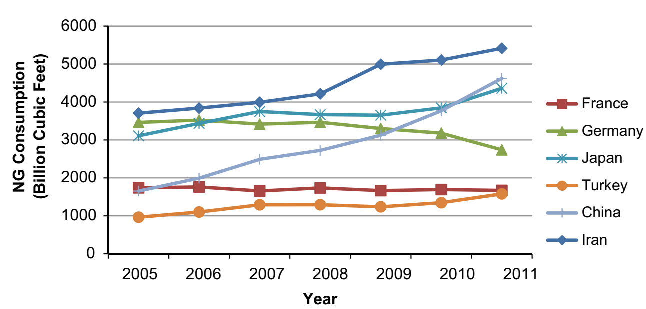
Graph 2. CO_2 emission trend of Iran and some middle east major countries [2].

2. System configuration

To harness solar energy a glazed liquid flat-plate collector is chosen. This instrument is installed on the roof of the building. Simultaneously two separate water routs are exist. In the first route water circulates through a loop therefore heats radiators and in the second path water flows to taps to meet washing demand. Fig. 3 shows schematic perspective of these routs and solar the absorber. As it is noted before, solar can only supply a fraction of needed energy thus, a gas heater should necessarily be installed for obtaining required temperature.

3. The case study circumstances

Initially Mashhad, a famous megacity in Iran, is chosen to study. This city is located in the North-East of Iran with geographical latitude of $+36.24$(N), longitude of -59.64(E) and elevation about 1000 m from sea level. There are many dwelling complex in this megacity. Our selected one is situated in the north-west of the city. This complex consists of 17 apartment blocks. Each block is a 4 stories building. There are two flats with total area of 220 m^2 in each story. Number of occupants is approximated 5 people per flat. STCs can be installed on the roof and facing to the south orientation for capturing maximum daily solar radiation. Buildings are constructed with steel structures, brick walls, concrete ceiling and one layer glaze windows. Thus, insulation is poor. Gas packages supply DHW and heating demand simultaneously. Therefore, actual amount of gas consumption leads us to real heating demand. These data are obtained from gas bills and Iran National Gas Company Statistics [6]. Tables 4 and 5 also documented monthly total consumption in 2011 and 2012, respectively. Also Graph 4 demonstrates a reasonable agreement between these two years gas consuming.



Graph 3. NG consumption trend of Iran and some major countries in the globe [2].

Table 3
Dry natural gas consumption trend in the middle east between 2005 until 2011 (billion cubic meter) [2].

Year	2005	2006	2007	2008	2009	2010	2011
Middle East	278.20	290.65	302.26	330.30	353.07	375.98	406.14
Bahrain	10.71	11.33	11.78	12.41	12.48	12.77	12.62
Iran	104.98	108.71	113.04	119.29	141.40	144.58	153.34
Iraq	1.45	1.80	1.46	1.88	1.15	1.30	0.88
Jordan	1.56	2.25	2.60	2.93	3.07	2.74	1.06
Kuwait	12.30	12.41	12.06	12.70	11.41	12.62	14.22
Oman	9.17	10.77	10.88	13.52	14.73	17.58	17.54
Qatar	18.70	19.61	19.70	20.20	21.10	21.80	19.53
Saudi Arabia	71.24	73.46	74.42	80.44	78.45	87.66	99.23
Syria	6.10	6.25	6.00	6.04	7.42	9.63	8.12
United Arab Emirates	41.25	43.09	49.17	59.44	58.58	60.54	75.40

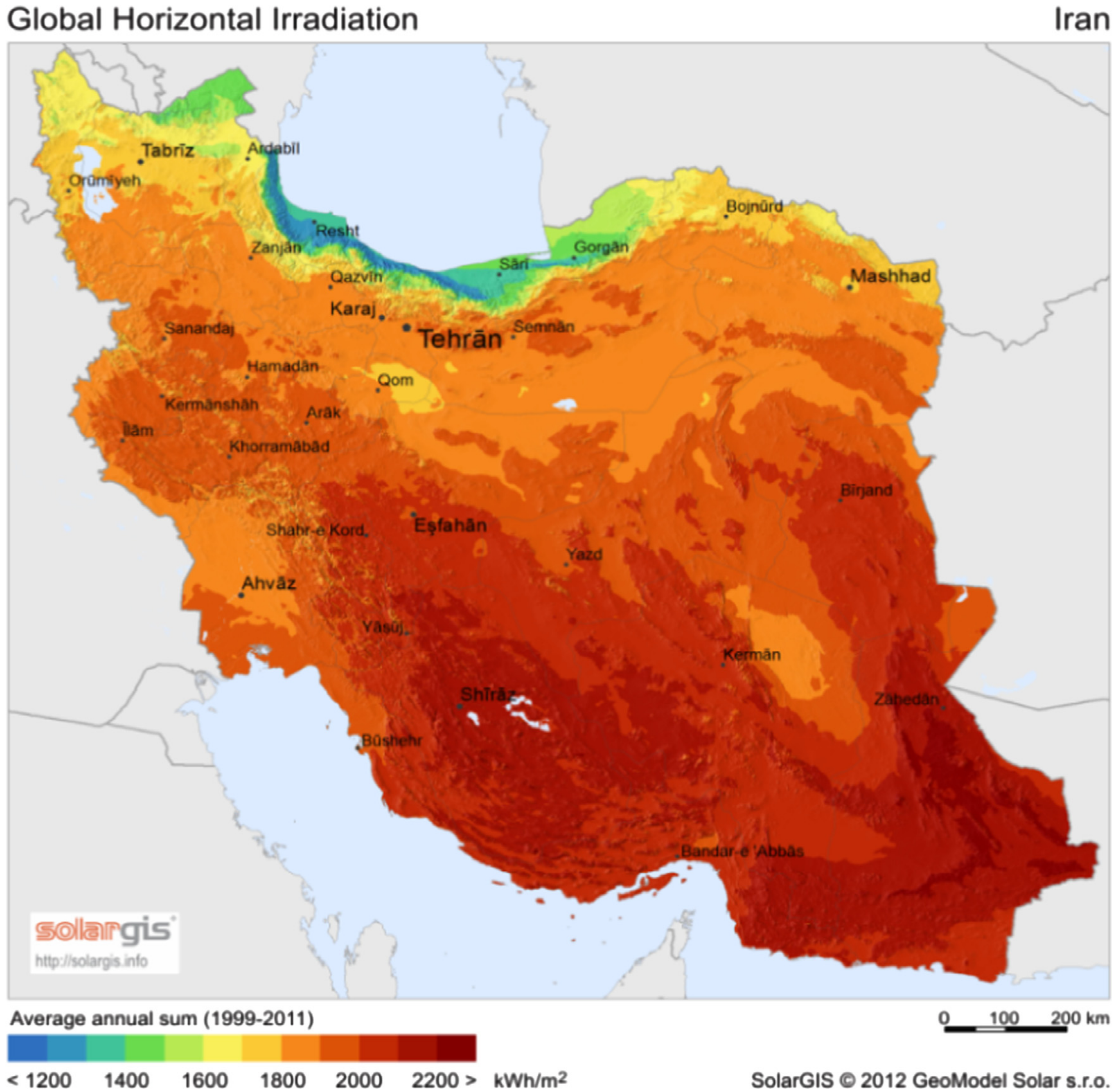


Fig. 1. Solar radiation map of Iran according to Solar GIS.

4. Domestic hot water and space heating load calculation

In this chapter the required load to provide DHW and space heating is calculated respectively. Inlet average water temperature for warm and cold month is measured 20 and 12 °C, respectively. According to water consumption study group of Mashhad Water & Wastewater Company [7] average water consumption per day per capita during last 20 years is about 110 L. Other required and conservative assumptions are as following: Graph 5.

Hot water consumption: 110 l/capita/day [7]
Water outlet temperature is adjusted at: 60 °C
Water specific heat (C_p): 4.19 kJ/kg °C [8]
Heat value of NG: 34 MJ/m^3 [9]

According to Mashhad climatic condition and also graph 14, NG consumption in MAY, Jun, July, August and Sep is minimum. Thus these months is considering as warm months of the year and the rest as cold ones.

DHW load in warm months including: May, Jun., July, August, Sep.
5 (person/flat) × 110 (l) × 1/1000 (m^3/l) = 0.55 m^3/day
0.55 (m^3/day) × 4190 (J/kg °C) × 1000 (kg/m^3) × (60 − 20) °C = 2857.58 MJ/month
Average gas consumption = 2857.58 (MJ/mol)/34 (MJ/m^3) = 84 m^3/month. It has reasonable correlation with actual ones in Tables 3 and 4
DHW load in cold month including: Jan, Feb., Mar., Apr., Oct., Nov., Dec.
0.55 (m^3/day) × 4.19 (kJ/kg °C) × 1000 (kg/m^3) × (60 − 12) °C = 3300 MJ/month
Average gas consumption = 3300 (MJ/month)/34 (MJ/m^3) = 97 m^3/month

Therefore, subtracting the volume of gas required to provide DHW from the actual consumption yields the gas demand to meet heating load in cold months. Tables 6 and 7 listed DHW and space heating demand for each month either in volumetric unit (m^3) or in energy unit (MJ) in 2011 and 2012.

So, according to Tables 4–7:
Annual total NG consumption = 3800 m^3/flat
Annul average NG consumption for DHW = 1100 m^3/flat
Annual average NG consumption for space heating = 3800 − 1100 = 2700 m^3/flat
Annual average DHW load = 37366 MJ/flat
Annual average heating space load = 128,500 MJ/flat ≅ 300 kWh/m^2 yr

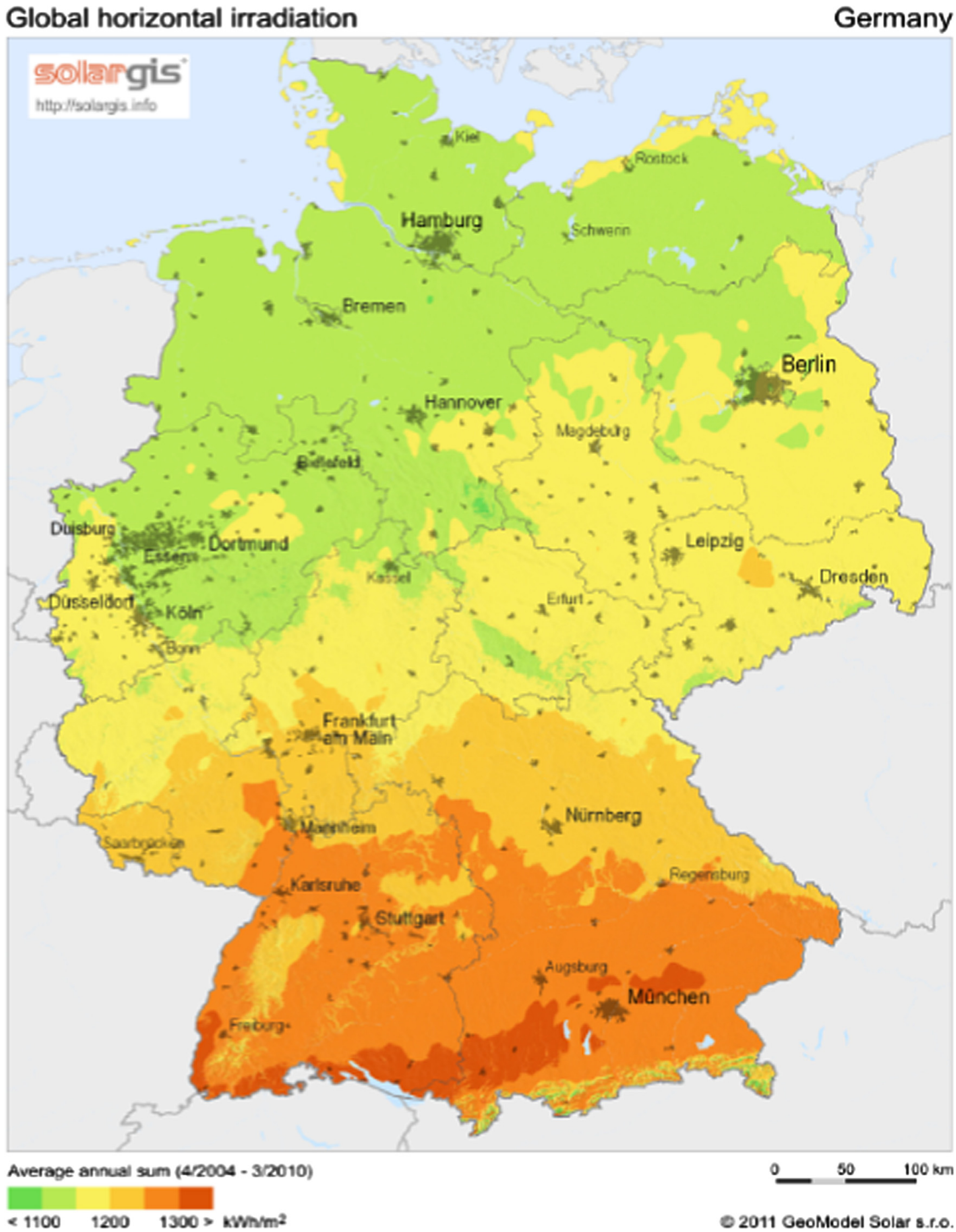


Fig. 2. Solar radiation map of Germany according to Solar GIS.

5. Net energy gain calculation by solar thermal collector

In this section, obtaining of net solar energy which can be captured by flat-plate collector is discussed. All of the required formulas are adapted form third edition of Solar Engineering of Thermal Processes book written by Duffie and Beckman [8]. To obtain net solar energy (Q) following equations should be calculated step by step [8].

$$\delta = 23.45\sin(360 \times (284+n)/365)$$

$$\cos(\theta) = \cos(\phi-\beta) \times \cos(\delta) \times \cos(\omega) + \sin(\phi-\beta) \times \sin(\delta)$$

$$\cos(\theta_z) = \cos(\phi) \times \cos(\delta) \times \cos(\omega) + \sin(\phi) \times \sin(\delta)$$

$$R_b = \cos(\theta)/\cos(\theta)_z$$

$$S = I_b \times R_b \times (\tau\alpha)_b + I_d(\tau\alpha)_d \times ((1+\cos\beta)/2)$$

$$Ra = g\Delta TL^3/(\nu \times \alpha \times T)$$

$$Nu = 1 + 1.44(1-1708(\sin 1.8\beta)^{1.6}/Ra\cos\beta) \times (1-1708/Ra\cos\beta) + ((Ra\cos\beta/5830)^{0.33}-1)$$

$$h_{c,p-c} = Nu \times k/L$$

$$h_{r,p-c} = \sigma(TP^2+TC^2)(T_p+T_c)/(1/\varepsilon p + 1/\varepsilon c - 1)$$

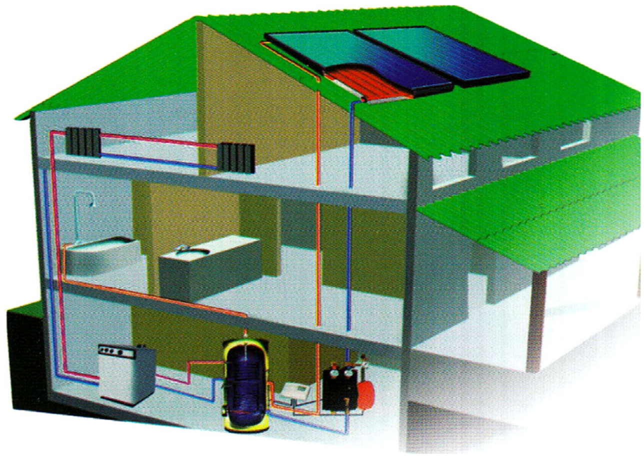
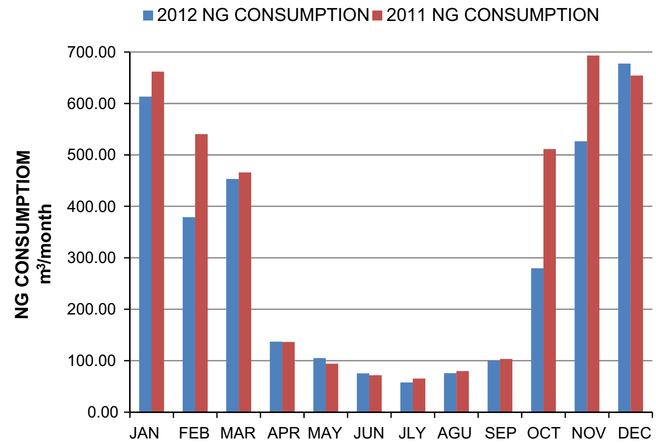


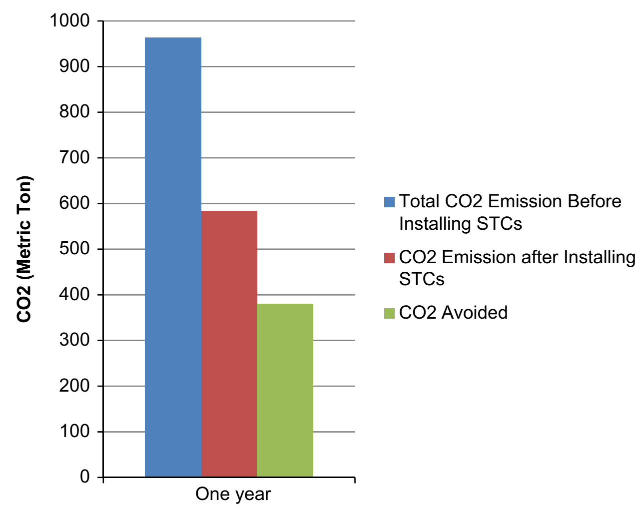
Fig. 3. Schematic perspective of solar absorber to meet residential heating load [own work].



Graph 4. The comparison of NG consumption in the dwelling of case study between 2011 and 2012 [own work].

Table 4
NG consumption in dwelling case study in 2012 according to gas bills.

Year 2012	Total consumption (m^3)	Consumption/unit (m^3)
Jan	83,434	613.49
Feb	51,553	379.07
Mar	61,655	453.35
Apr	18,652	137.15
May	14,307	105.20
Jun	10,237	75.27
Jly	7,823	57.52
Agu	10,325	75.92
Sep	13,630	100.22
Oct	38,060	279.85
Nov	71,597	526.45
Dec	92,139	677.49
Total	473,412.00	3480.97



Graph 5. Results of installing STCs environmental benefits from aspect of CO_2 avoided [own work].

Table 5
NG consumption in dwelling case study in 2011 according to gas bills.

Year	Total consumption (m^3)	Consumption/unit (m^3)
Jan	90,000	661.76
Feb	73,484	540.32
Mar	63,378	466.01
Apr	18,570	136.54
May	12,801	94.13
Jun	9,742	71.63
Jly	8,880	65.29
Agu	10,861	79.86
Sep	14,055	103.35
Oct	69,540	511.32
Nov	94,278	693.22
Dec	88,969	654.18
Total	554,558.00	4077.63

Table 6
DHW and space heating demand in 2012 of case study.

Year 2012	DHW (m^3)	Heating (m^3)	DHW (MJ)	Heating (MJ)
Jan	97.00	516.49	3,298	20,858.50
Feb	97.00	282.07	3,298	12,888.25
Mar	97.00	356.35	3298	15,413.75
Apr	97.00	40.15	3,298	4,663.00
May	84.00	21.20	2,856	3,576.75
Jun	84.00	0.00	2,856	2,559.25
Jly	84.00	0.00	2,856	1,955.75
Agu	84.00	0.00	2,856	2,581.25
Sep	84.00	0.00	2,856	3,407.50
Oct	97.00	182.85	3,298	9,515.00
Nov	97.00	429.45	3,298	17,899.25
Dec	97.00	580.49	3,298	23,034.75
Total	1099	2409.04	37,366	118,353.00

$$h_{r,c-a} = \varepsilon c \times \sigma(T_c^2 + T_s^2)(T_c + T_s)$$
$$U_t = (1/(h_{c,p-c} + h_{r,p-c}) + 1/(h_w + h_{r,c-a}))^{-1}$$
$$m = (U_t/(K\delta))^{0.5}$$
$$F = t_{gh}(m/2 \times (W-D))/(m/2 \times (W-D)$$
$$F_1 = (1/U_t)/W[1/(U_t(D + (W-D)F + 1/(\pi \times D \times hf))$$
$$F_2 = m_1 \times C_p/(A_c \times U_t \times F_1) \times (1 - \exp(A_c \times U_t \times F_1/m_1 \times C_p))$$
$$F_R = F_1 \times F_2$$
$$Q = A_c \times F_R \times (S - U_t(T_i - T_a))$$

To compute above equations some technical specifications of solar absorber are needed. According to existence models in marketing and measured values these parameters are tabulated in Table 8.

Also, Table 9 depicts required properties of water and air that are involved in achieving solar energy via absorber.

Besides, environmental variables such as I_b, I_d, T_a are also adapted from 2009 ASHRAE Handbook-Fundamentals [8]. In this

Table 7
DHW and space heating demand in 2011 of case study.

Year 2011	DHW (m^3)	Heating (m^3)	DHW (MJ)	Heating (MJ)
Jan	97.00	564.76	3,298	22,500.00
Feb	97.00	443.32	3,298	18,371.00
Mar	97.00	369.01	3,298	15,844.50
Apr	97.00	39.54	3,298	4,642.50
May	84.00	10.13	2,856	3,200.25
Jun	84.00	0.00	2,856	2,435.50
Jly	84.00	0.00	2,856	2,220.00
Agu	84.00	0.00	2,856	2,715.25
Sep	84.00	0.00	2,856	3,513.75
Oct	97.00	414.32	3,298	17,385.00
Nov	97.00	596.22	3,298	23,569.50
Dec	97.00	557.18	3,298	22,242
Total	1099	2994.50	37,366	138,639.50

Table 8
Collector design parameters according to marketing and measured values.

Solar collector specifications	**Symbol**	**Unit**	**Value**
Collector surface	A_c	m^2	4
Plate			
Plate to cover spacing	L	mm	25
Emmitance	Ec	Unitless	0.95
Mean plate temperature	T_p	C	110
Abosorbtance coefficient	A	Unitless	0.93
Thickness	δ	mm	0.50
Thermal conductivity (copper)	K_p	W/m °C	385
Glass			
Transmittance	τ	Unitless	0.83
Glass emmitance	εG	Unitless	0.88
Cover temperature (measured)	T_c	°C	50
Mean temp. between cover and plate (measured)	T	°C	68
Tube			
Tube spacing	W	mm	150
Diameter	D	mm	10
Heat transfer coefficient inside tube	hf	W/m °C	300
Inlet temperature	T_i	°C	40

Table 9
Constant parameters and material properties [7].

Stefan–Boltzman constant	σ	$W/m^2 K^4$	5.67E−08
Kenematic viscosity of air	ν	m^2/s	1.96E−05
Thermal conductivity of air	K	W/m K	2.93E−02
Thermal diffusivity of air	α	m^2/s	2.69E−05
Water specific heat	C_p	kJ/kg °C	4.19
Mass flow rate	m_1	kg/s	0.03

case for any station with specific WMO (World Meteorological Organization) number various environmental variables are tabulated. Table 10 lists these data for Mashhad.

6. Results and discussion

Based on previous section illustrations monthly and annually average energy which can be gain by flat-plate collector are calculated. Additionally, solar fraction for DHW (f_{DHW}) and for heating demand ($f_{Heating}$) are obtained respectively. These values are summarized in Table 11.

Based on above calculations:
$\Sigma Q = 25{,}558$ MJ/year
$f_{DHW} = \Sigma Q$/Annual average DHW load $= 25{,}558/37{,}366 = 68\%$
$f_{Heating} = \Sigma Q$/Annual average heating space load $= 25{,}558/128{,}500 = 19.8\%$

Table 10
Mashhad radiation data [8] WMO#: 407450.

Month	I_b	I_d	T_a
Jan	2.92	0.5	2.9
Feb	2.75	0.72	5.3
Mar	2.39	1.044	9.1
Apr	2.26	1.202	15.4
May	2.25	1.24	20.4
Jun	2.23	1.23	25.7
Jly	2.21	1.206	27.8
Aug	2.33	1.09	26.6
Sep	2.45	0.92	21.6
Oct	2.4	0.8	16
Nov	2.43	0.63	9.6
Dec	2.76	0.48	4.7

Lat: 36.27N Long: 59.63E Elev: 999 StdP: 89.89 Time Zone: 3.50 (IRN).
WMO: World Meteorological Organization number.
I_b: Average beam radiation (MJ/m^2 h).
I_d: Average diffuse radiation (MJ/m^2 h).
T_a: Average ambient temperature.

Table 11
Average monthly and annual absorbed solar energy and fraction.

Month	Q (MJ)	f_{DHW} (%)	$f_{Heating}$ (%)
Jan	2,901.75	87.99	13.91
Feb	2,328.04	70.59	18.06
Mar	1,859.69	56.39	12.07
Apr	1,664.50	50.47	35.70
May	2,179.20	76.30	60.93
Jun	2,221.41	77.78	86.80
Jul	2,266.56	79.36	115.89
Aug	2,385.80	83.54	92.43
Sep	1,984.43	69.48	58.24
Oct	2,054.76	62.30	21.59
Nov	2,219.57	67.30	12.40
Dec	1,491.94	45.24	6.48
Annual	25,557.65	68	19.8

Total annual energy saving $= (68\% \times 37366 + 19.8\% \times 128{,}500) = 50{,}852$ MJ
Total annual fuel saving $= 50{,}852$ (MJ)/34 (MJ/m^3) $= 1495$ m^3
Annual fuel should be purchased $= 3800 - 1495 = 2305$ m^3
Percentage of saved total annual energy demand $= 50{,}852/(128{,}500 + 373{,}660 \times 100 = 30.6\%$
NG tariff in Iran in residential sector $= 0.12$ US\$/m^3
Total annual economy $= 1495$ (m^3) $\times$ 0.12 (\$/m^3) $= 180$US\$
2 Number of collector (4m^2 of square area) cost besides piping $= 700$ US\$
Invest return time $= 700/180 = 4$ years
Total collector operation life $= 20$ years
Specific density of NG $= 0.679$ kg/m^3[9]
CO_2 in flue gas $= 2.744$ kgCO_2/kg fuel [9]
Total annual fuel saving $= 1495 \times 0.679 = 1015$ kg
Total CO_2 avoided for whole of the case study complex $= 1015 \times 2.744 \times 136 = 380$ t/yr

7. Conclusion

In this research, we scrutinized some statistics in terms of NG consumption and subsequently CO_2 emission because of flaring this fuel between Iran, Middle East and some developed countries

initially. The considerable share of Iran besides rising trend in this issue is concerning in recent years. In second step heating energy demand in residential buildings, in Mashhad the second major city in Iran, is obtained 300 kWh/m^2 yr, according to actual NG combustion, that is almost three times in European cold climate cities [10]. In third step to recommend an auxiliary energy source, for mitigating CO_2 emission, a solar thermal collector designed. Finally calculations indicated that 68% of domestic hot water and 20% of heating space load can be met by solar absorber annually. Nevertheless, this choice will lead to avoid 2.8 MT of CO_2 per year for each residential dwelling. This is not the net carbon dioxide avoided whereas the emitted amount during STCs manufacturing should be taken into account in globally aspect. Actually the information in related to manufacturing is not in access at the present but can be a new topic of study. Even though, widely utilizing of renewable appliances such as PV panels or STCs in some parts of the world such as southern Europe, China, Turkey or USA may be convincing for being environmental friendly of these technologies manufacturing. Despite of, suitable renewable energy potentials such as wind or solar in Iran, but due to rich hydrocarbon resources besides their cheap prices there is not sufficient tendency and motivation for government to legislate appropriate regulations regarding renewable energy issue. Although, Iran Renewable Energy Organization (SUNA) has been attending to this matter since 1995 in order to only achieve updated information and technology in connection with utilization of renewable energy resources and measurement of potentials (solar, wind, geothermal, hydrogen and biomass) [11]. However, this study shows changing aspects for substituting energy supplier from conventional fuels to sustainable and renewable ones can be either economic or environmental friendly even in poor insulated residential flats. As a matter of fact, the need of energy will never over for humankind besides hydrocarbon fuel resources will deplete eventually. Additionally, paying attention to sustainable development also forces us to substitute another suitable energy supplier alternative. Definitely, great potential in harnessing solar energy in Mashhad or many similar locations in Iran can be an appealing opportunity and powerful persuasion for government policy in subsidizing to promote and support renewable technologies utilization.

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